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Biodiversity: Origin, function and threats*

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Resum. Tot i que ens ha costat molt de temps adonar-nos-en, finalment s'ha evidenciat que l'enorme capital biològic de la Terra és una riquesa igual o, fins i tot, més valuosa que la riquesa material i cultural. No obstant això, és tristament irònic que el coneixement que comencem a guanyar sobre la biodiversitat del planeta i el paper important que té en el funcionament del món i dels nostres propis assumptes ha arribat en un moment històric en què la nostra espècie ataca aquesta biodiversitat en tots els fronts possibles. En commemoració de l'Any Internacional de la Biodiversitat 2010, aquest article explora què és la diversitat biològica o biodiversitat i per què és important, quins són els problemes que afronta, les principals causes d'aquests problemes i el que un ciutadà mitjà hi pot fer. Els nous objectius del Conveni de Biodiversitat per a l'any 2020 inclouen la gestió i explotació sostenible de les poblacions d'animals i plantes aquàtiques, l'augment de les terres i les zones costaneres protegides i la reducció dels nivells de contaminació que són nocius per als ecosistemes i la biodiversitat, entre d'altres. El que hi ha en joc és no solament la supervivència de la varietat d'organismes del planeta, sinó també els serveis ambientals que aquests duen a terme i que són totalment necessaris per a nosaltres, per no parlar de la nostra pròpia supervivència com una altra espècie en la biosfera.

Paraules clau: biodiversitat · ecodiversitat · sostenibilitat · Any Internacional de la Biodiversitat

Summary. Even though it has taken us a long time to realize, it has finally become clear that the vast biological capital of the Earth is a wealth which is equally or even more valuable than material and cultural wealth. Yet, it is sadly ironic that the knowledge we are beginning to gain about the planet's biodiversity and its important role in the functioning of the world and our own affairs has come at a time in history when our species is assaulting this biodiversity on all possible fronts. In commemoration of the International Year of Biodiversity 2010, this article explores what biological diversity or biodiversity is and why it is important, what problems it is confronting, the main causes of these problems, and what the average citizen can do about them. The new objectives for 2020 of the Biodiversity Convention include the sustainable management and exploitation of aquatic animal and plant populations, to raise protected land and coastal areas and to lower pollution levels that are harmful for ecosystems and biodiversity, among others. What is at stake is not only the survival of the variety of organisms on the planet but also the environmental services they perform, which are totally necessary for us, not to mention our own survival as yet another species in the biosphere.

Keywords: biodiversity · ecodiversity · sustainability · International Year of Biodiversity

The year 2010 was declared the International Year of Biodiversity (Fig. 1), and all sorts of events and activities were held with the goal of letting society know what biodiversity is and what problems it is facing. What is biological diversity or biodiversity? Why is it important? What problems is it confronting? What are the causes of these problems, and what can the average citizen do about them?

At the United Nations' Conference on the Environment and Development held in Rio de Janeiro in 1992, a number of countries approved the Convention on Biological Diversity, which had three objectives: to protect the biological diversity, to sus-

Fig. 1. Logo of the International Year of Biodiversity as commemorated in the territories of Catalan language and culture.

* Based on the lecture given by the author at the Institute for Catalan Studies, Barcelona, on 29 April 2009 for the celebration of Earth Day at the IEC (*1a Jornada de Sostenibilitat i Canvi Climàtic*).

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tainably use its components, and to fairly and equitably share the benefits that this sustainable use yields. Since then, the terms 'sustainability' and 'biodiversity' have become part of our everyday vocabularies. However, it is not clear whether either one is fully understood by lay people; we shall talk about biodiversity, but we shall also refer to sustainability at some point in this text.

Little-known wealth

Two kinds of wealth have traditionally been acknowledged as a country's assets: material wealth (the kind that concerns mainly economists and bankers) and cultural wealth (the terrain cultivated by historians, artists, intellectuals, etc.). Even though it has taken us a long time to realize, it has finally become clear that there is another kind of wealth: the vast biological capital of the Earth, which is equally or even more valuable than the others and is the kind that concerns naturalists, botanists, zoologists, ecologists, and their peers.

Biodiversity is the richness and variety of species of living beings, but it is also the biological wealth considered at other scales, ranging from the genetic one (genic variability within a given species of bacterium, fungus, plant or animal) to the taxonomical (different categories immediately under the species such as sub-species, varieties and breeds, and immediately above it such as genera, families, etc.), and even the geographical one (different geographical areas that also contain different numbers of species). In an easily understandable simile, Ramon Margalef said that biodiversity is like the 'dictionary' (Fig. 2) of nature: the exhaustive inventory of all the flora and fauna in a given region, or on the entire Earth. Ecodiversity or ecological diversity would be the 'grammar': the proportions among the different components and the way they are organized and interact within ecosystems, just as grammar enables us to organize words to form intelligible texts, be they literary, technical, or poetic.

The 'grammar' of nature is still largely unknown to us, but what we do know points to the fact that there are certain rules for building ecosystems. Here are a few: today's ecosystems are the outcome of both the interaction of their components and an evolutionary, geological and biological history. This history dates far back in time and has undergone losses through individual extinction and episodes of mass extinction, but also gains through speciation, evolutionary radiation, and the invasion of allochthonous species. There are species that are crucial for ecosystems to function smoothly, while other species are relatively commonplace and exchangeable. There is a direct relationship between ecological diversity and the stability of ecosystems, but a certain degree of disturbance also encourages biodiversity. All species, from the humblest to the most visible and showy, play a role in cycling nutrients, producing and consuming organic materials, providing less obvious ecosystem services which we rarely consider (composition of the atmosphere itself, soil formation, purification of polluted water, soil and air, the climate itself, etc.) or the production of natural resources (foods, medicines, building materials, etc.), which we more consciously appropriate. The different ecosystems and the entire biosphere depend to a greater or lesser extent on the species of living beings, and as yet another species, so do we.

Fig. 2. Biodiversity is the dictionary of nature (original by Joan-Albert Ros).

How many species are there?

In the past 250 years, taxonomists have described around 1.8 million species of living beings, and there are reasonable estimates that the total might be between 15 and 30 million species on Earth today, or perhaps even more. Of these species, some are more abundant, active, and transformative of their environment than others; they are the bulwark of ecosystems because they allow other species to move in (as happens with trees and forests, with coral and coral reefs, etc.). Other species, despite their abundance, do not seem to play such an important role and (perhaps because we do not know enough about them) seem ordinary and even redundant or replaceable: if they did not exist, perhaps the ecosystem in which they live would not suffer from their loss (Fig. 3).

Other species, though not very numerous, play an essential role because they exert control over others, leading us to regard them as keystone species: without them the entire ecosystem (or much of it) would crumble or radically change. Predators and pathogenic organisms are examples of these. Finally, yet others, precisely because they are few, rare, and relegated to small habitats, seem to be the last holdouts of lineages that might have once been successful but now (for a host of reasons not always known) seem to be in the homestretch of a process of extinction, which is actually common to all species, although it may take place along many millions of years.

Without realizing it, we have used the term 'ecosystem,' which should be defined as follows: the ecosystem is the entire set of species that live in a given environment: a forest, a lake, a

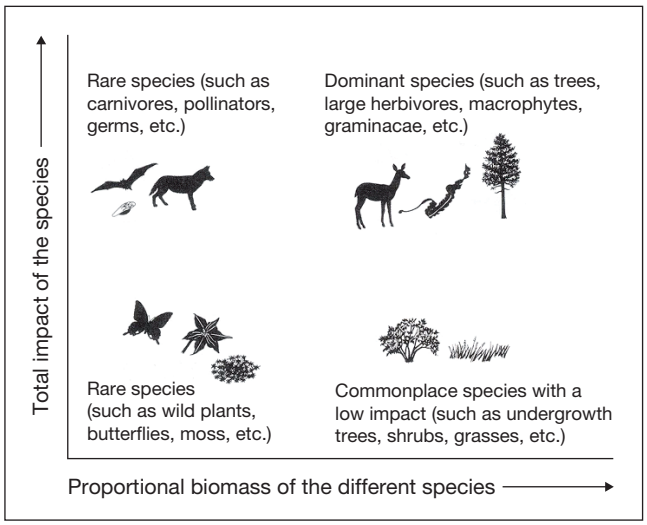

Fig. 3. The species of organisms can be classified into four major groups according to whether they are important to the ecosystem because of their abundance, whether they are not important despite their abundance, whether they are not important because they are very scarce, and whether they are important despite the fact that they are scarce. These are the keystone species [40,41].

sea, etc.; *plus* their inanimate, geological, physical, and chemical environment; *plus* the interactions among these species, from simple physical coexistence to predation, and including all kinds of more or less complex relations, such as competition, symbiosis, and mutualism; *plus* the interactions between the species and their inanimate environment. Therefore, ecosystem is a theoretical yet also very real concept. We could compare it to 'society' in human affairs, or 'trade,' or even 'civilization.' This enables us to also call to mind other approaches to understanding the role of the species and their respective abundance, meaning that different species of organisms in their environments may resemble what we human beings do in our societies: there are different 'professions,' some of them crucial and others less so. Some jobs are performed by just a few specialists, while other, perhaps less complex jobs are performed, either better or worse, by a multitude of people; they are the generalists and for that very reason they are interchangeable and/or expendable.

While we have known for some time that certain regions are extremely diverse (tropical rainforests, coral reefs) and that others function with a small number of species, recent discoveries have opened up unexpected windows onto the biological richness of geographic areas that were assumed to be thoroughly researched already or inhospitable to life. This is true of what are called subsurface lithoautotrophic microbial ecosystems, made up of bacteria and fungi which occupy the pores of igneous rocks located at a certain depth within the Earth's surface (up to three kilometres or deeper), which get energy from inorganic chemical substances without the need for organic input from the surface. A similar phenomenon can be found in the abyssal 'oases,' fertile islands in a truly deserted environment: the bottom of the sea where the Earth's crust is generated. Around the hydrothermal vents which pour water that has been heated to dozens or hundreds of degrees into the sea and operate as continuous geysers, two decades ago a community made up of strange worms and other animals was discovered, unknown to science until then. Not only were there new species, there were also entirely new taxonomic groups. What made this discovery extraordinary, in addition to the abundance of organisms that existed in contrast to the poverty of the abyssal bottoms of all oceans, was the fact that the trophic webs of these oases were not based on plant photosynthesis, as the most common systems both on land and in the sea are. Here, the primary producers are chemosynthetic bacteria, deriving energy from reduced metals (especially sulphur) dissolved in the water expelled from the vents and seeps; these bacteria live independently in the environment or form strange symbioses with different invertebrate species.

According to recent studies, underwater canyons, guyots or mountains, and other geographical features rising up from the sea bottom also contain fauna unlike those of the surrounding sea floor, with examples of multiple speciation reminiscent of what has been known about land for years, where isolated valleys in high mountain chains, tepuis, and oceanic islands are the home to endemic flora and fauna. On land, studies of geographically remote areas are resulting in the majority of new species discovered, chiefly insects and plants. However, in some cases these discoveries are surprising because they involve large animals that have gone unnoticed by science until very recently. The best-known cases are the discoveries of mammals, birds, amphibians, and reptiles in jungle regions all over the world. Something similar has happened in the oceans, where giant species have recently been discovered, ranging from bacteria ('giant' because they are visible to the naked eye: one to two millimetres in size) to squid and sharks. Some of these species, about which science knew nothing until quite recently, play an important ecological role: one cyanobacterium of marine picoplankton, *Prochlorococcus marinus*, can be extremely abundant (up to 100,000 cells ml^{-1}), and its photosynthetic activity might account for around one-third of the total primary production in the oceans.

A huge undertaking

As greater surveying efforts and the use of molecular tools are expanding the taxonomic catalogue of biodiversity, it is also becoming clear that decades, if not centuries, will be needed to perform the enormous undertaking of cataloguing the entire biological diversity of the different ecosystems on Earth at the rate we are doing so now. The situation is particularly serious because the blossoming of certain branches of biology (molecular, genetic, ecological, etc.) has led to a decline in taxonomy among young biologists; today there are many taxonomic groups with only a single specialist in the entire world, or two at most, and they are often professionals on the verge of retirement. The solution may be found in initiatives like the one launched by the *Instituto Nacional de Biodiversidad* (National Biodiversity Institute) of Costa Rica and other, similar centers, particularly in countries where there are "hotspots" with extremely rich flora and fauna (tropical, Mediterranean, and other regions). In the studies conducted by these centers, the first

screening and tentative classification of the specimens collected are performed by parataxonomists, people with little formal training in taxonomy but with sound knowledge of the local flora and fauna. Later, specialists in laboratories, universities, and museums from all over the world would perform the more intricate work. The establishment of databases that are constantly updated and have good morphological and anatomical images and the ability to consult them via the Internet, such as the one promoted by the All Species Foundation, as well as the rapid exchange of information among experts and amateurs made possible by the worldwide web, should contribute to facilitating this comprehensive biodiversity census, which may be utopian yet is also necessary.

It may be too late

It is sadly ironic that the knowledge we are beginning to gain about the planet's biodiversity and its important role in the functioning of the world and our own affairs has come at a time in history when our species is assaulting this biodiversity on all possible fronts: destroying habitats (especially tropical rainforests, but also temperate forests, wetlands, and coastal areas all over the world), directly eliminating some of the most fragile species and propagating others (domestic, anthropophilic, pests, weeds; in short, commonplace species), polluting the environment, and exhausting what for us are natural resources but for the ecosystems involved are crucial elements in their functioning. And we are imposing this destruction at a point in history when humanity is having serious problems just feeding almost two-thirds of its growing population. Referring to the simile above, we are indiscriminately tearing out entire pages from that dictionary even before we make the effort to find out what they contain or to profit from the potential benefits of the information.

The ecosystems simplified by mankind (crop fields, polluted rivers, cities, exploited forests, and overfished coastal areas) operate with a lower number of species (and fewer interactions among them) than unaltered ecosystems (or ones that have been barely altered, since our species' footprint stretches to practically every corner of the planet). However, we do not know to what extent we can keep losing biodiversity. Therefore, aware that what has been described until now is only a tiny fraction of the total possible species inhabiting out planet, we must be judicious and apply the principle of precaution before it is too late.

The efforts to conduct a detailed study of some species have revealed their imperilled situation (Fig. 4). The same holds true for certain communities in which the erosion of biodiversity is extreme (such as mangrove swamps and coral reefs among marine systems; tropical rainforests, Mediterranean ecosystems, tectonic lakes and oceanic islands among terrestrial systems). There are increasing cases of vertebrate species (mainly mammals and birds) whose populations include such a small number of individuals that their survival is unfeasible. Some of these species (such as the black rhinoceros, the Bengal tiger, the snow panther, etc.) have more specimens living in zoos and circuses than in nature.

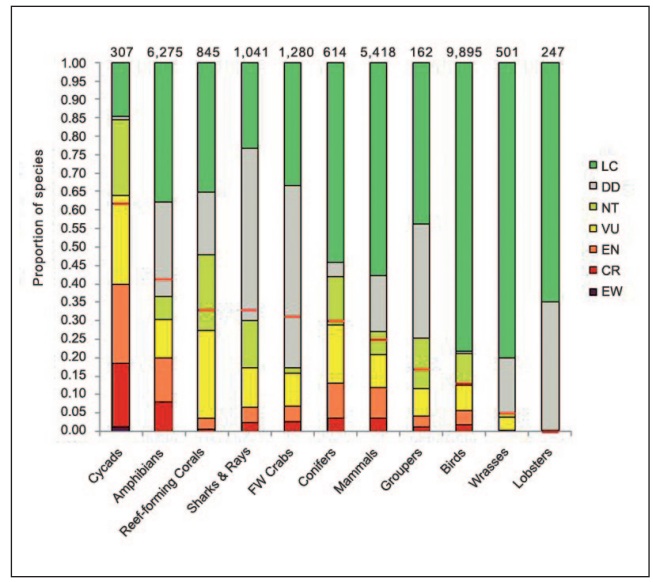

Fig. 4. The number of threatened species (ranging from slightly threatened to almost extinct) is quite high and steadily rising. LC: least concern; DD: data deficient; NT: near threatened; VU: vulnerable; EN: endangered; CR critically endangered; EW: extinct in the wild. Reproduced with permission of IUCN (International Union for Conservation of Nature).

The so-called 'charismatic mega-fauna' species (large animals that our species admires), such as the panda, the tiger, the mountain gorilla, the Mediterranean monk seal, and the bald eagle, play a twofold role. First, they are important species in their ecosystems, in some cases 'keystone species' on which many others and thus the overall functioning of the entire community depend, and secondly they are attractive to the public at large and for this very reason capable of stimulating campaigns to protect them and their habitats. This boosts knowledge of them, while they are also used as indicators of the conservation status of species and habitats and of the efforts our society makes to protect them. For this reason, it is worrisome that so many of them are in the terminal stage, in the sense that they are just a step away from extinction. This is the case of the lynx on the Iberian Peninsula, probably the only large mammal species currently in danger of extinction in Europe (where many other species have already disappeared or remain heavily protected, such as the bear, Przewalski's horse, the European bison, and the bearded vulture).

The drama of the loss of some of these species through extinction is not merely aesthetic or scientific (due to the disappearance of unique, unrepeatable organisms that are the evolutionary response to adaptation to given environments) nor solely ethical (our species tends to be the cause of these extinctions and we are therefore collectively responsible for them). Even more worrisome is the loss of the ecological function that these species perform in their environment, which cannot always be replaced. For example, on the African savannah, the domesticated livestock herds introduced through European colonization do not produce even half the meat per hectare that the autochthonous ungulates do, are much more susceptible to illnesses, and deplete the natural vegetation in such a way that it cannot recover.

Cascades of erosion

The triggering of a cascade of effects that can totally transform the appearance, structure, and functions of the affected communities has had very dire consequences. In this sense, it is believed that the disappearance or rarefication of large terrestrial and aquatic animals, either herbivores or carnivores, mostly for anthropic reasons over the past 11,000 years (the approximate date of the major expansion of the human species around all the continents after the retreat of the ice from the last glaciations) drastically transformed the terrestrial and aquatic ecosystems. Something similar is happening today, with human intrusions into tropical regions all over the planet, with the overfishing of one fishing ground after another in the seas all over the world, and with the trade in exotic species, either living, stuffed or in the guise of skeletons, pelts or hard parts (horns, shells, etc.). The impact of these misdeeds has prompted notable changes in the planet's ecosystems. This can be the case of the proliferation of jellyfish, which seem to have multiplied in recent years. Not only are they bothersome to summertime swimmers, but in some ecosystems they have also replaced large fish as the predators of small fish and their larvae, thus impacting not only natural communities but also fishing stocks. One of the causes of this proliferation of jellyfish is a decline in their predators (sea turtles and fish), but another is the huge surplus of plankton, which is no longer being consumed by the fish that we have been constantly overfishing for centuries now.

There are hopeful initiatives. The number of protected areas on both land and sea, in which the exploitation of natural resources is banned or severely limited, is steadily rising (another issue is the efficacy of these protective measures; they have often been criticized as 'paper parks' in the sense that they confer protection only on paper but they are not supported by budgets adequate to fund enforcement, surveillance, or research). Ecotourism, the visit to some of these protected areas, brings many more benefits than the conventional exploitation of animal and plant species, but the very frequency of the visitors to these parks or reserves is also one of the causes of their degradation; this should be regulated and some areas where visits are not allowed should be set aside as permanent sanctuaries.

The acquisition of natural lands by governments, organizations, or private individuals in order to spare these lands from agricultural or urban development or from forestry uses is an effective strategy, and not only in developing countries. Many conservationist NGOs, environmentally-committed companies, foundations, and private individuals pay relatively affordable prices that allow them to purchase thousands or millions of hectares of jungle or forest whose protection can be negotiated with the governments of the countries involved. Bioprospecting (searching for natural resources in plant and animal species) has furnished hundreds of new molecules, produced by terrestrial and marine organisms, whose characteristics make them useful as medicines. The realization that biodiversity can be industrially profitable will also help to conserve it.

What can we do?

However, right now, the pace at which biodiversity is being eroded and lost outstrips the efforts to conserve it. Slowing down the loss in biodiversity at the local, regional, and global scales means securing the protection, compensation, restoration, and rational and sustainable management of the wealth that biodiversity is. And this should be done through a skilful mix of scientific research aimed at learning more about the components and role of biodiversity, capital investment to create sustainable markets instead of the consumers and squanderers that we have now, and governance to smooth the thorny coexistence between economic growth and conservation. Conserving biodiversity requires the efforts of everyone in all fields. It requires a change in attitudes at work as professionals, at home, on the street as citizens, and when we act as consumers, tourists, and voters. All of our decisions ultimately affect the conservation of biological diversity in the short or long term. Since there are no neutral decisions, the way we can contribute to improving the conservation of the biological diversity in our neighborhood, our district, our country and, by extension, the world is by accepting our responsibility from the very start.

Readers might ask what the average citizen's responsibility for the loss of biodiversity is and therefore what can be done to prevent or reduce it. Assuming that this average citizen is not a hunter, fisher, or pyromaniac, and thus directly attacking biodiversity, we should bear in mind that we are all to a greater or lesser extent consumers of resources that directly or indirectly affect the integrity of species and ecosystems. I shall cite a few examples, which can be appreciated in greater detail when reading books and articles on the issue (such as those included in the bibliography) or simply by scanning the daily newspaper.

It is within our reach

The exotic animal stands that had peppered Barcelona's Ramblas for decades were only recently removed. The animals sold there, some of them illegally (because they were protected species), were just a small fraction of those that had been captured in their original habitats, jungles, and forests all over the world, because many of them died in the process of capture, transport, and maintenance. After being purchased by poorly informed citizens, many of them escaped (such as parrots and snakes) or were abandoned because they became dangerous as they grew (such as turtles and alligators). In the alien environment into which they were released, these animals either died or they adapted, but often creating havoc in our rivers (Florida turtles have displaced autochthonous ones all over temperate Europe) and to local crops (parrots harm fruit trees). The trade in exotic animals (which has not stopped despite the removal of those stands) harms both the native and the host ecosystems.

There is still a worse despoilment of diversity than these exotic 'pets'. Mollusc shells, coral (tropical madreporaria and Mediterranean red coral), bird feathers, ivory, gorilla hands, rhi-

noceros horns, and tiger and seal penises, among other goods, are a constant drain on biodiversity for totally gratuitous ends ('decorative' objects), if not clearly false ones (purported aphrodisiacs or cures, according to the Asian pharmacopeia). Halfway between this despoilment and that of the hunting activities is the harvesting of medicinal plants, mistletoe and moss (for Christmas celebrations!), the capture of songbirds and other follies that demonstrate not only the Neolithic roots of our customs but also wholesale ignorance of the role these organisms play in their natural habitats.

We inhabitants of the shores of the Mediterranean are huge fish consumers, even though fish are no longer so plentiful off our shores and now come from fishing grounds virtually all over the world. Therefore, far-off fishing grounds are exploited to supply our markets. Yet what is more, the fish that we usually eat tend to be first-, second- or third-level carnivores, which are much fewer in number than herbivores. (On Earth, in general, we feed on plants and herbivores, that is, from the first and second levels of the trophic pyramid, the most abundant.) A very simple measure for lowering the pressure on these fish populations would be to preferentially eat species located further down in the trophic pyramid, the planktophages (such as sardines and other blue fish, which are also very healthy). At the same time, we would lower the loss in species that control their ecosystems, such as carnivores everywhere. For anyone interested, there are lists of fish species (and other animal species) whose consumption is innocuous for our ecosystem, and others (such as many species of tuna) that are seriously threatened and whose days are numbered. The consumer of fish (or whatever else) should not turn a blind eye to this situation.

The same holds true for other resources whose exploitation directly impacts natural habitats. Most of the deforestation of the African and Asian jungles is to harvest precious wood (which ends up being part of the furniture sold all over the world) or to set up plantations growing cocoa, coffee, or other plants from whose products we benefit. It is clear that we cannot do without some of these products, but we can purchase only those that decent, trustworthy organizations certify have been produced without harming their natural habitats, that is, sustainably.

In contrast, the tropical and sub-tropical jungles and forests in the Americas seem to be suffering particularly acutely from the pressure of deforestation to clear for pastures or corn fields (which might be used for biofuels), or to grow soy, which is omnipresent in our foods today. It is evident that a balanced diet also includes meat protein, but we citizens of Western countries overdo beef consumption (and for this reason, new pastures must be cleared for increasingly large herds). It is evident that dwindling oil has to be replaced by other fuels, but surely not at the expense of harming the natural habitats to plant sugar cane and corn there. Soy has a high protein content, but this does not justify transforming forests and scrubland into immense soy fields. And we could say the same about many resources whose exploitation would not come at the cost of a vast erosion of biodiversity if they were used more carefully and sustainably. If our ecological footprint is excessive, eliminating the part of it that we can dispense with would help to compensate for the ecosystems that we have been depleting for centuries.

What does the future hold for us?

Future prospects are not promising. We are far from achieving sustainable exploitation of the planet's resources, and there are more and more people on Earth who must be fed and are demanding lifestyles closer to those of the developed countries. I began this article by explaining that 2010 has been declared International Year of Biodiversity. When the 10th conference of the parties of the Biodiversity Convention met in Nagoya last October to note the headway that had been made since the previous convention, the governments acknowledged that the overall objective, a significant drop in the loss of biodiversity, had not been achieved despite a few local, minor successes and a trend towards greater awareness among individuals and governments.

The new objectives for 2020 set by the signatory countries of the Biodiversity Convention include, among others:

- To ensure sustainable management and exploitation of aquatic animal and plant populations.
- To significantly lower the anthropic pressure on coral reefs.
- To eradicate or properly control certain exotic invasive species.
- To raise the protected land area to at least 17% and the protected coastal and marine area to at least 10%.
- To stave off the extinction of seriously threatened species.
- To lower pollution to levels that are innocuous for ecosystems and biodiversity.
- To cut the rate of natural habitat loss at least by half.
- To restore at least 15% of the depleted ecosystems.
- To eliminate subsidies for activities that directly or indirectly have a negative effect on biodiversity.

We can hope that when a new conference of the parties meets a decade from now, the headway in these areas and the results of these objectives are more promising than they were in Nagoya. What is at stake is not only the survival of the variety of organisms on the planet but also the environmental services they perform, which are totally necessary for us, not to mention our own survival as yet another species in the biosphere.

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